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EP 0 153 017 B1

Description

This invention relates to a continuous flow electrophoretic separator, and in particular to an inlet means therefor.

A continuous flow electrophoretic separator comprises a cylindrical stator, a concentric tubular rotor defining an annular chamber between the stator and the rotor, an electrode incorporated in the stator, an electrode incorporated into the rotor, means for causing a carrier liquid to flow through the chamber, and an inlet means in the stator for injecting a migrant material into the carrier liquid. In operation, an electric field is applied radially across the annular chamber between the electrodes, carrier liquid is caused to flow through the annular chamber, and the rotor is rotated about the stator so as to stabilise laminar flow in the chamber. Migrant material injected into the carrier liquid is thus subjected to electrophoretic separation.

An example of a continuous flow electrophoretic separator is described in GB-A-1 186 184 (& US-A-3 616 453), and modifications to that example are described in GB-A-1 431 888 and GB-A-1 431 887 (& US-A-3 844 926), and in GB-A-1 578 809 (& US-A-4 149 957). Such separators may be used to fractionate an inlet stream into a plurality of outlet streams.

GB-A-1 431 887 (& DE-A-2 344 671) describes a continuous flow electrophoretic separator wherein the inlet means includes a supply duct for the supply of the migrant material, an annular chamber, and a circumferential slot around the periphery of the stator. The annular chamber contains a porous material through which the migrant material is constrained to flow, before emerging through the slot. This provides a smooth and even flow of migrant into the carrier liquid. Howerer it is difficult to clean such a porous material, so that such an inlet means is not suitable where the migrant material includes cells or large biologically-active molecules.

According to the present invention there is provided a continuous flow electrophoretic separator as hereinbefore defined, having a substantially cylindrical stator including an inlet means for a migrant material, the inlet means comprising:

a supply duct for the supply of the migrant material, a first annular chamber, and a circumferential slot around the periphery of the stator, and characterized in that the inlet means also comprises:
a plurality of ducts providing communication between the supply duct and the first annular chamber,
a second annular chamber coaxial with the stator and in fluid communication with the slot,
and as plurality of channels providing fluid communication between the first annular chamber and the second annular chamber,

the arrangement being such that in use the flux of the migrant material is substantially the same through all parts of the slot.

Desirably the number of channels is at least twice the number of ducts, and the channels and the ducts are equally spaced, none of the channels being aligned with the ducts. The ducts and the channels may extend in radial directions and may lie in planes perpendicular to the axis of the stator. The slot may also lie in a plane perpendicular to the axis of the stator, and desirably is not aligned with the channels.

The inlet means may be fabricated in a rigid plastics material, or even in a metal such as stainless steel, which is surprising in view of the proximity of the inlet means to the electrodes of the separator.

The invention will now be further described by way of example only and with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic medial sectional representation of an electrophoretic separator;

Figure 2 is a medial sectional view of an inlet means of the electrophoretic separator of Figure 1;

Figure 3 is a medial sectional view of an alternative inlet means to that of Figure 2; and

Figure 4 is a view on the line IV-IV of Figure 3.

Referring to Figure 1, an electrophoretic separator 10 is shown similar in principle to those described in the aforementioned patent specifications. The separator 10 comprises a rigidly mounted cylindrical stator 12, and a concentric tubular rotor 14 rotatably connected to the stator 12 by a bearing 16 at its upper end and drivable by means of a stub shaft 18 attached to the lower end of the rotor 14. The lower end of the stator 12 is spaced apart from the rotor 14 by a bearing 20 through which liquid is free to flow. The stator 12 incorporates a cylindrical electrode 24 along a portion of its length, and the rotor 14 incorporates a tubular electrode 26 in opposed relationship to the electrode 24 so as to define an annular chamber 28 between the two electrodes 24 an 26 which, in operation of the separator 10, electrophoresis takes place. A duct 30 extends through the stator 12 to a port 32 at the lower end of the stator 12, and a duct 34 extends through the stator 12 to communicate with a slot 36 around the perimeter of the stator 12 below the lower end of the electrode 24. Thirty discharge ducts 40 (only four of which are indicated by broken lines) extend through the stator 12 from thirty axially displaced positions on the surface of the stator 12 above the upper end of the electrode 24. For further details with respect to the construction of the electrophoretic separator 10 reference is directed to the aforementioned specifications.

In operation of the separator 10, a potential difference is applied between the two electrodes 24 and 26 so as to set up a radial electric field across the annular chamber 28, and the rotor 14 is rotated about the stator 12. A carrier liquid 44 is supplied down the duct 30 to the port 32, flowing through the bearing 20 and upwards between the stator 12 and rotor 14 to emerge through the discharge ducts 40. A migrant material is caused to flow down the duct 34 to emerge from the slot 36 into the carrier liquid 44, and is carried upwards through the annular chamber 28. As a result of its passage through the electric field, the migrant is electrophoretically separated into its components, which follow radially separate paths through the chamber 28, and hence emerge through different discharge ducts 40. The flow of carrier liquid 44 and migrant material through the separator 10 is thus fractionated into thirty outlet streams emerging from the thirty ducts 40.

In Figure 1 the inlet means for the migrant material is represented diagrammatically by the duct 34 and the slot 36. A pratical inlet means must provide a smooth and steady flow of migrant material which must emerge in such a manner as not to disrupt the laminar of the carrier liquid 44. If, as in Figure 1, the migrant material emerges form a slot 36 extending completely round the periphery of the stator 12, then the flux of the migrant material should be substantially equal from all parts of the slot 36, and the slot 36 should be sufficiently narrow to produce a well-defined layer of migrant material within the carrier liquid 44 at the lower end of the annular chamber 24.

Referring to Figure 2, there is shown an inlet means for the electrophoretic separator of Figure 1. Below the electrode 24 (not shown in Figure 2) the stator 12 comprises an unplasticised polyvinylchloride (uPVC) generally cylindrical end member 50, with an upper portion 52 of the same diameter as the electrode 24, and a lower portion 54 of smaller diameter. Between the lower portion 54 and the upper portion 52 are a square circumferential step 56 and above that an upwardly sloping conical shoulder 58, there being a circumferential groove 60 between the step 56 and the shoulder 58. The duct 34 for the supply of migrant material extends axially through the end member 50 to communicate with six equally spaced radial holes 66 (only two of which are shown) extending to the surface of the lower portion 54 below the step 56. The duct 30 (see Figure 1) for the carrier liquid extends through the end member 50 parallel to the axis, and is not in the plane of the Figure.

An intermediate part 68 of the lower portion 54 is threaded, and between the holes 66 and the threaded part 68 is a circumferential groove 70 to locate an O-ring seal 72. A uPVC cylindrical sleeve 74 of the same external diameter as the upper portion 52 fits over the end member 50, engaging with the threated part 68 and extending between the shoulder 58 and the lower end of the threated part 68. The internal surface of the sleeve 74 is substantially complementary to the surface of the end member 50, with an upwardly sloping shoulder 78 and a square circumferential step 76, and below the step 76 part of the sleeve 74 is relieved so as to define with the end member 50 an annular chamber 80 with which the holes 66 communicate, the chamber 80 being sealed at its lower end by the O-ring seal 72.

The shoulder 78 is spaced apart from the shoulder 58, so as to define a circumferential slot 82, by a washer 84 between the horizontal parts of the steps 56 and 76. Thirty-six equally spaced shallow grooves 86 extend radially across the horizontal part and axially along the vertical part of the step 76, thus providing communication between the annular chamber 80 and an annular chamber 88 defined by the groove 60 and the sleeve 74.

Below the threaded part 68 the lower portion 54 is of slightly reduced diameter and is covered by a close-fitting cylindrical sleeve 90 of polytetrafluoroethylene (PTFE) held in position by three recessed screws 92 (only one of which is shown). The sleeve 90 bears against the bearing 20 (see Figure 1).

In operation of the inlet means of Figure 2, the migrant material is caused to flow down the duct 34, and flows outwardly through the six holes 66 into the annular chamber 80. It then flows through the thrity-six grooves 86 into the annular chamber 88, and through the slot 82 to emerge as a narrow layer into the carrier liquid 44 (see Figure 1). The slot 82 and the grooves 86 each provide resistance to the flow of migrant material so that there is a steady pressure difference between the chamber 80 and the chamber 88, and between the chamber 88 and the open end of slot 82, and consequently that the flow is substantially the same through each groove 86, and is substantially equal through all parts of the slot 82.

It has hitherto been believed that, in view of the proximity of the inlet means to the electrodes 24 and 26 (see Figure 1), all parts of the inlet means in contact with the migrant material or with the carrier liquid 44 should be made of an electrically insulating material. It was expected that any conducting material near the electrodes 24 and 26 would become electrically polarized by the electric field and therefore bring about electrolysis, with consequent generation of bubbles. Surprisingly it has been found that bubble generation does not occur when parts of the inlet means are of a conducting material such as stainless steel and are electrically insulated from the electrode 24 while the carrier liquid 44 is flowing through the electrophoretic separator 10, and an alternative inlet means for the electrophoretic separator of Figure 1 is shown in Figure 3, to which reference is now made, in which the stator 12 includes a stainless steel end member 100 electrically insulated from the electrode 24 (see Figure 1) by a hollow cylindrical insulating block 102 of Delrin acetal of the same external diameter as the electrode 24. The end member 100 comprises a cylindrical portion 104 of the same diameter as the electrode 24, below which extends a cylindrical portion 106 of smaller diameter covered by a close-fitting tubular Delrin® acetal sleeve 108 held in place by three recessed screws 110 (only one of which is shown). The cylindrical portion 104 has a plane upper surface 112 from which extends axially a boss portion 114 of about a third the diameter of the cylindical portion 104. The upper end 116 of the boss portion 114 is threaded to engage within the hollow insulating block 102, and an annular stainless steel plate 122 of the same external diameter as the cylindrical portion 104 is sandwiched between the block 102 and the surface 112 of the cylindrical portion 104, fitting closely around the lower part of the boss portion 114. Two O-ring seals 124 in grooves 126 around the unthreaded part of the boss portion 114 provide seals between the boss portion 114 and the insulating block 102 and the plate 122 respectively, while an O-ring seal 128 locates in a groove 130 on the upper face of the plate 122 to seal between the plate 122 and the block 102.

Referring also to Figure 4, the duct 34 for the migrant material extends axially through the boss portion 114 to communicate with six equally spaced radial holes 134 which extend to the surface of the boss portion 114 about 1 mm above the surface 112. The lower face of the plate 122 is spaced away from the surface 112 by a thin annular washer 136 and

is relieved so as to define, in combination with the washer 136 and the boss portion 114, an annular chamber 140 with which the holes 134 communicate. Twelve equally spaced radial grooves 142 in the lower face of the plate 122 extend from the chamber 140 to an annular groove 144 in the lower face of the plate 122, the inside diameter of the groove 144 being the same as the external diameter of the washer 136. A circumferential slot 150 is thus defined between the lower face of the plate 122 and the surface 112, beyond the edge of the washer 136. The width of the slot 150 is defined by the thickness of the washer 136, and is typically chosen to be between 0.15 mm and 0.4 mm depending on the viscosity of the migrant material. The plate 122 is oriented so that the holes 134 are aligned midway between alternate pairs of the grooves 142. The duct 30 (see Figure 1 and Figure 4) for the carrier liquid extends through the end member 100 parallel to the axis.

In operation of the inlet means of Figures 3 and 4 the migrant material is caused to flow down the duct 34, and flows outwardly through the six holes 134 into the annular chamber 140. It then flows through the twelve grooves 142 into the annular groove 144, and through the slot 150 to emerge as a narrow well-defined layer into the carrier liquid 44 (see Figure 1). The grooves 142 and the slot 150 each provide resistance to the flow of migrant material so that there is a steady pressure difference between the chamber 140 and the annular groove 144, and between the annular groove 144 and the open end of the slot 150, and consequently that the flow is substantially the same through each groove 142, and is substantially equal through all parts of the slot 150.

In a modified version (not shown) of the inlet means of Figures 3 and 4, the part of the surface 112 defining the slot 150 is stepped upwardly to be level with the upper surface of the grooves 142, and the opposed part of the lower surface of the plate 122 is stepped upwardly by the same distance. Consequently the slot 150 is in a plane slightly higher than the plane of the grooves 142, so that after assembling the apparatus and commencing flow of a liquid through the duct 34 any air in the grooves 142 tends to be swept out of the open end of the slot 150.

The use of stainless steel components to define the slot 150, rather than plastics materials such as uPVC, leads to the advantage that the width of the slit 150 is more stable in operation since the thermal expansivity of steel is about a tenth that of plastics materials. Furthermore the components are less prone to be damaged accidently during assembly and disassembly of the electrophoretic separator, and if desired they can be heat-sterilized.

Claims

1. A continuously flow electrophoretic separator comprising a cylindrical stator (12), a concentric tubular rotor (14) defining an annular chamber (28) between the stator and the rotor, an electrode (24) incorporated in the stator, an electrode (26) incorporated into the rotor, means (30, 32) for causing a carrier liquid to flow through the chamber, and an inlet means in the stator for injecting a migrant material into the carrier liquid, said inlet means comprising:

a supply duct (34) for the supply of the migrant material,
a first annular chamber (80, 140), and
a circumferential slot (82, 150) around the periphery of the stator,
and characterised in that the inlet means also comprises:
a plurality of ducts (66, 134) providing communication between the supply duct (34) and the first annular chamber (80, 140),
a second annular chamber (88, 144) coaxial with the stator and in fluid communication with the slot (82, 150),
and a plurality of channels (86, 142) providing fluid communication between the first annular chamber (80, 140) and the second annular chamber (88, 144),

the arrangement being such that in use the flux of the migrant material is substantially the same through all parts of the slot.

2. An electrophoretic separator as claimed in Claim 1 wherein the number of channels (86, 142) is at least twice the number of ducts (66, 134), the channels are equally spaced, the ducts are equally spaced, and none of the channels are aligned with the ducts.

3. An electrophoretic separator as claimed in Claim 1 or Claim 2 wherein the ducts (134) and the channels (142) extend in radial directions and lie in planes perpendicular to the axis of the stator (12).

4. An electrophoretic separator as claimed in any one of the preceding Claims wherein the slot (150) lies in a plane perpendicular to the axis of the stator.

5. An electrophoretic separator as claimed in any one of the preceding Claims wherein the slot (82, 150) is not aligned with the channels (86, 142).

6. An electrophoretic separator as claimed in any one of the preceding Claims wherein the circumferential slot (150) is defined between metal portions (104, 122) of the inlet means.

7. An electrophoretic separator as claimed in any one of the preceding Claims wherein the slot (82, 150) is of width between 0.15 mm and 0.4 mm.

Revendications

1. Séparateur par électrophorèse à circulation continue, comprenant un stator cylindrique (12), un rotor tubulaire concentrique (14), délimitant une chambre annulaire (28) entre lui-même et le stator, une électrode (24) incorporée au stator, une électrode (26) incorporée au rotor, un dispositif (30, 32) destiné à provoquer la circulation d'un véhicule liquide dans la chambre, et un dispositif d'introduction dans le stator, destiné à injecter une matière de migration dans le véhicule liquide, le dispositif d'introduction comprenant:

un conduit (34) d'alimentation en matière de migration,
une première chambre annulaire (80, 140), et

une fente circonférentielle (82, 150) placée à la périphérie du stator, et
caractérisé en ce que le dispositif d'introduction comporte aussi:
plusieurs conduits (66, 134) assurant la communication entre le conduit d'alimentation (34) et la première chambre annulaire (80, 140),
une seconde chambre annulaire (88, 144) coaxiale au stator et communiquant avec la fente (82, 150), et
plusieurs canaux (86, 142) assurant la communication entre la première chambre annulaire (80, 140) et la seconde chambre annulaire (88, 144),

l'arrangement étant tel que, pendant l'utilisation, le flux de la matière de migration est pratiquement le même dans toutes les parties de la fente.

2. Séparateur par électrophorèse selon la revendication 1, dans lequel le nombre de canaux (86, 142) est au moins égal au double du nombre de conduits (66, 134), les canaux sont régulièrement espacés, les conduits sont régulièrement espacés, et aucun des canaux n'est aligné sur les conduits.

3. Séparateur par électrophorèse selon l'une des revendications 1 et 2, dans lequel les conduits (134) et les canaux (142) sont disposés en directions radiales et se trouvent dans des plans perpendiculaires à l'axe du rotor (12).

4. Séparateur par électrophorèse selon l'une quelconque des revendications précédentes, dans lequel la fente (150) se trouve dans un plan perpendiculaire à l'axe du stator.

5. Séparateur par électrophorèse selon l'une quelconque des revendications précédentes, dans lequel la fente (82, 150) n'est pas alignée sur les canaux (86, 142).

6. Séparateur par électrophorèse selon l'une quelconque des revendications précédentes, dans lequel la fente circonférentielle (150) est délimitée entre des parties métalliques (104, 122) du dispositif d'introduction.

7. Séparateur par électrophorèse selon l'une quelconque des revendications précédentes, dans lequel la fente (82, 150) a une largeur comprise entre 0,15 et 0,4 mm.

Patentansprüche

1. Elektrophoretischer Separator mit einem zylindrischen Stator (12), einem konzentrischen rohrförmigen Rotor (14), der eine Ringkammer (28) zwischen dem Stator und dem Rotor bildet, einer Elektrode (24), die mit dem Stator vereinigt ist, einer Elektrode (26), die mit dem Rotor vereinigt ist, einer Einrichtung (30, 32), um eine Trägerflüssigkeit zu veranlassen, durch die Kammer zu strömen, und einer Einlasseinrichtung im Stator, um ein Wandermaterial in die Trägerflüssigkeit zu injizieren, wobei die Einlasseinrichtung die folgenden Merkmale aufweist:

eine Speiseleitung (34) zur Zufuhr des Wandermaterials,
eine erste Ringkammer (80, 140), und
ein Umgangsschlitz (82, 150) rund um den Umfang des Stators,
dadurch gekennzeichnet, dass die Einlasseinrichtung auch die folgenden Merkmale aufweist:
eine Anzahl von Leitungen (66, 134), die eine Verbindung zwischen der Speiseleitung (34) und der ersten Ringkammer (80, 140) herstellen,
eine zweite Ringkammer (88, 144), die koaxial zum Stator angeordnet ist und in Strömungsmittelverbindung mit dem Schlitz (82, 150) steht, und
mehrere Kanäle (86, 142), welche eine Strömungsmittelverbindung zwischen der ersten Ringkammer (80, 140) und der zweiten Ringkammer (88, 144) herstellen,

und dass die Anordnung so getroffen ist, dass bei der Verwendung der Fluss des Wandermaterials durch alle Teile des Schlitzes im wesentlichen gleich ist.

2. Elektrophoretischer Separator nach Anspruch 1, wobei die Anzahl von Kanälen (86, 142) mindestens das Doppelte der Anzahl der Leitungen (66, 134) beträgt, dass die Kanäle mit gleichem Abstand angeordnet sind, dass die Leitungen mit gleichem Abstand angeordnet sind, und dass keiner der Kanäle auf die Leitungen ausgerichtet ist.

3. Elektrophoretischer Separator nach Anspruch 1 oder Anspruch 2, wobei die Leitungen (134) und die Kanäle (142) sich in radialen Richtungen erstrecken und in Ebenen liegen, die senkrecht zur Achse des Stators (12) stehen.

4. Elektrophoretisches Separator nach jedem der vorangehenden Ansprüche, wobei der Schlitz (150) in einer Ebene senkrecht zur Achse des Stators liegt.

5. Elektrophoretischer Separator nach jedem der vorangehenden Ansprüche, wobei der Schlitz (82, 150) nicht auf die Kanäle (86, 142) ausgerichtet ist.

6. Elektrophoretischer Separator nach jedem der vorangehenden Ansprüche, wobei der Umfangsschlitz (150) zwischen Metallabschnitten (104, 122) der Einlasseinrichtung festgelegt ist.

7. Elektrophoretischer Separator nach jedem der vorangehenden Ansprüche, wobei der Schlitz (82, 150) eine Breite zwischen 0,15 mm und 0,4 mm aufweist.

Fig.1.

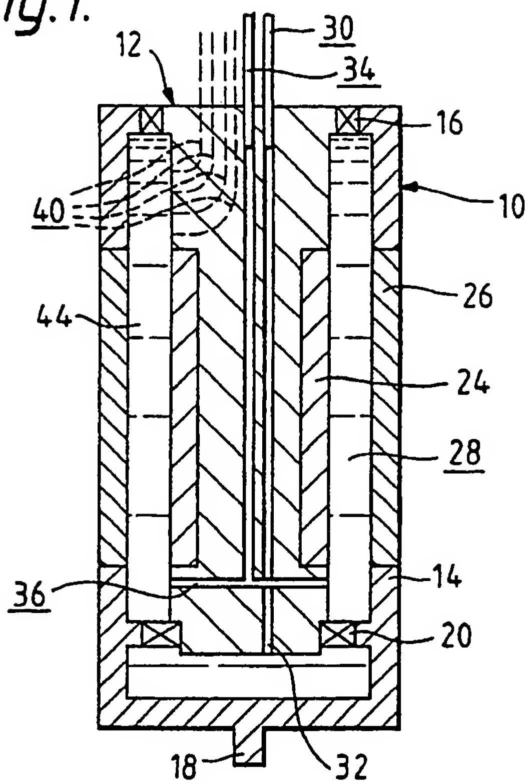
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Fig.2.

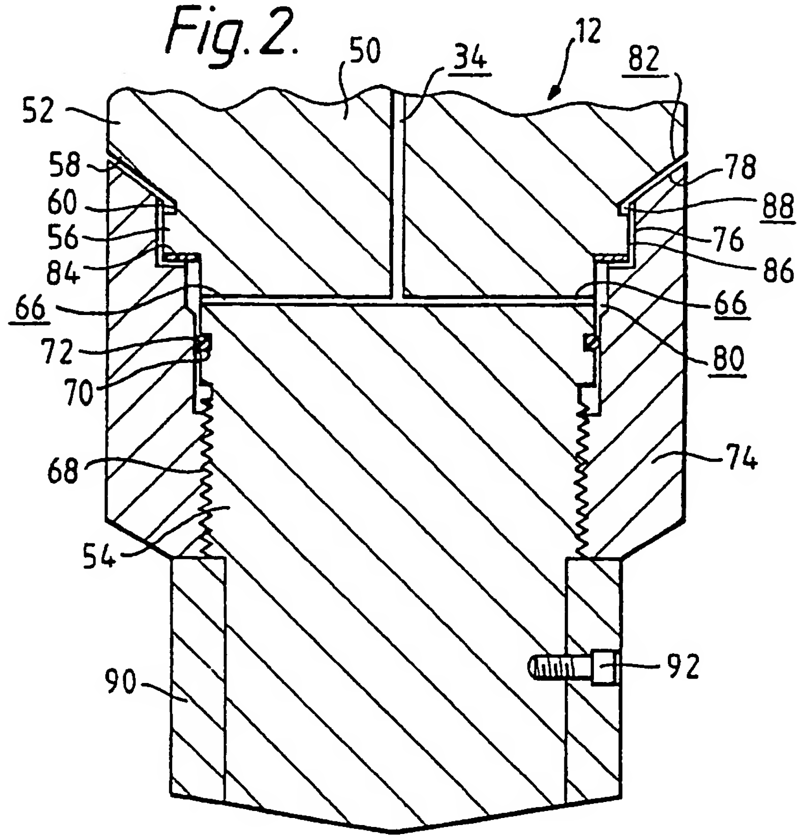
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Fig.3.

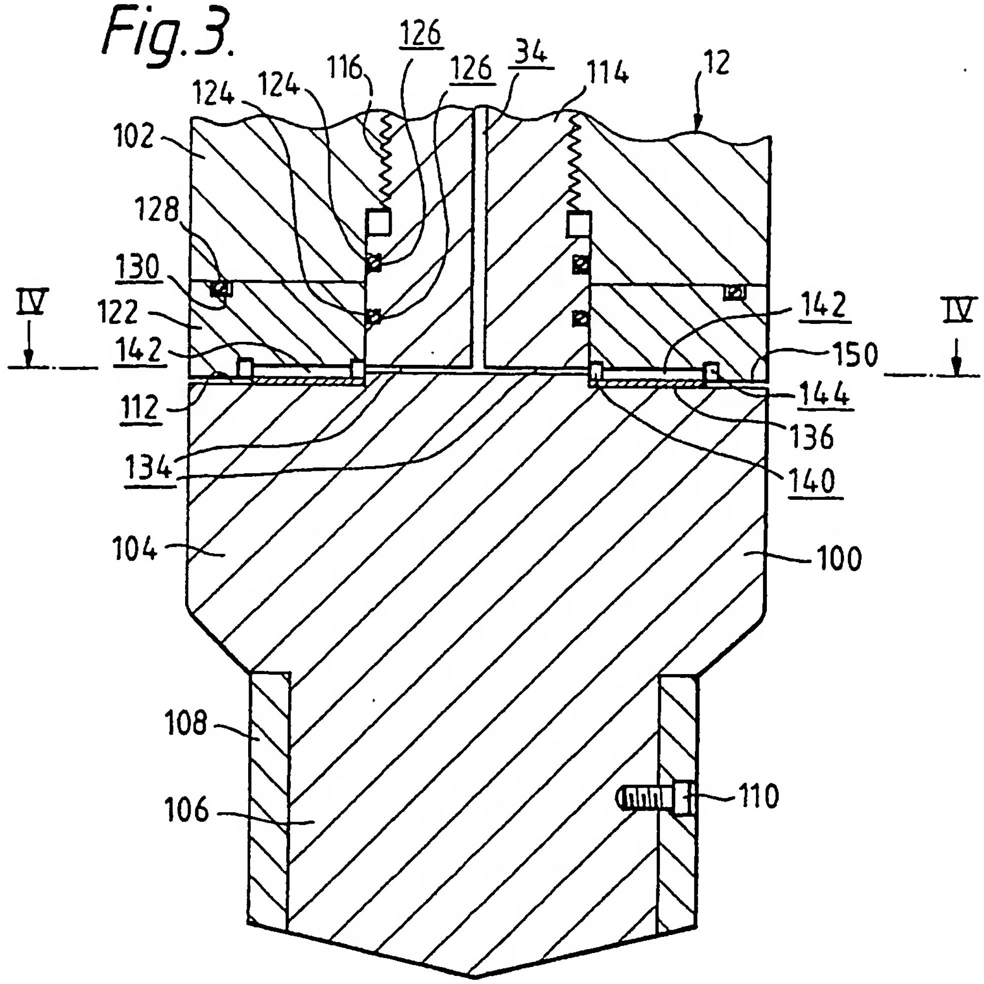
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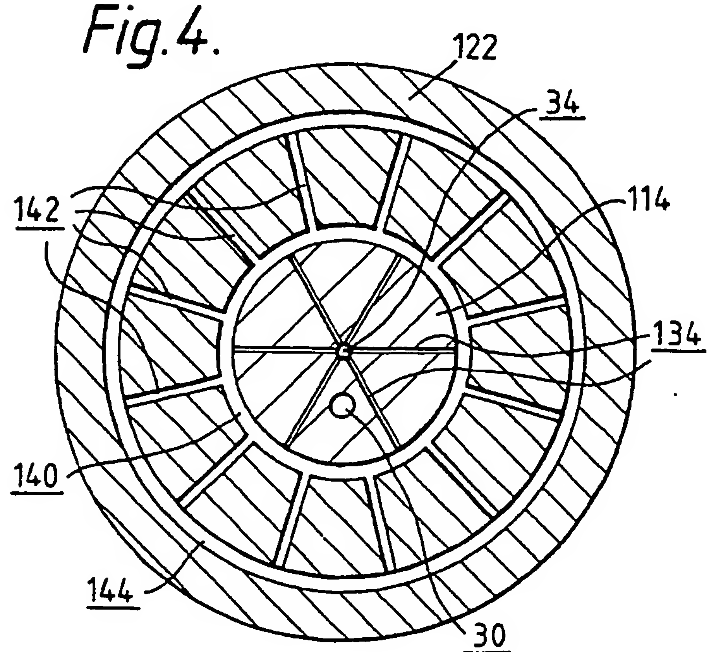
Fig.4.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